

SIMULATION OF UNCONTROLLED HALF-WAVE RECTIFIER USING SIMULINK-MATLAB

Vicky Salamena

Electrical Engineering Study Programme, Politeknik Negeri Ambon
Email : vickysalamena@gmail.com

ABSTRACT

This research utilizes the features of the simulink-matlab program to analyze the characteristics of a single-phase uncontrolled half-wave rectifier. The rectifier circuit is built using the existing facilities in the simulink in the matlab program, then performs the simulation process by running the simulink program so as to produce the input and output voltage and current curves of the rectifier. The curve is displayed by the scope window which can also display the values of these quantities. The waveforms and current values of the simulation results will be compared with the results of theoretical calculations, so that the compatibility of the simulation and theoretical values can be known. These values are the output voltage and current of the rectifier, namely the average voltage (DC) and the effective voltage (rms). The simulation results of the simulink-matlab program can display the rectifier output waveform, namely the output voltage and the output current as well as the rectifier input voltage and current (and), and can also display the parameters of the rectifier output waveform, namely the maximum and minimum peak values, both values the peak value can be calculated the average voltage (DC) and effective voltage (rms) as the supply voltage to the load and can display the rectifier output current characteristic curve based on the current equation.

From the results of the discussion there is a difference between the results of theoretical calculations and the results of calculations using the simulation results parameters in the simulink-matlab program, this is due to the presence of diode parameters that are also included in the simulation process. By using the matlab-simulink feature, the diode characteristics can be adjusted according to the specifications, as well as the rectifier characteristics with freewheeling diodes.

Keywords: single-phase-rectifier, simulink-matlab, rms-voltage, voltage-average

INTRODUCTION

In analysing the output characteristics of rectifiers, it is usually done analytically using mathematical models of sinusoidal waveforms that supply rectifiers connected to the working principles of rectifier elements (diodes, thyristors etc.). The goal is to see the waveform and determine the value of the voltage and current that supplies the rectifier load. In this research study, the process of analysing a single-phase uncontrolled half-wave rectifier uses the features of the matlab program by utilising the simulink facility. In simulink-matlab, a rectifier circuit can be created consisting of a voltage source, rectifier construction and electrical load model (resistance and inductance). After this circuit is run (running) will be able to see the input and output waveform

curves of the rectifier along with the values of these quantities. The quantities displayed are the peak value of the voltage and current sine waves, their maximum and minimum values, the average value and the rms value of the voltage and current shapes. The values of the simulation results are then compared with the results of theoretical calculations so as to validate the suitability of the simulated values. The simulated values that are in accordance with the results of theoretical calculations are values that can be used to analyse the characteristics of the rectifier after being simulated using the simulink-matlab program. The result of this research is to benefit from the features of the matlab program that are in accordance with the characteristics of the rectifier, so that it can be used to analyse the performance of a single-phase uncontrolled half-wave rectifier.

METHODS

This research makes use of the features of the matlab program to display the output wave curve of a single-phase uncontrolled half-wave rectifier so as to analyse the characteristics of the rectifier against the load connected to it. The procedures carried out in the research are as follows:

1. Modelling the uncontrolled half-wave rectifier circuit into a test circuit in the matlab-simulink program.
2. Running simulations of the rectifier circuit with purely resistive and resistive-inductive loads.
3. Calculating the rectifier output voltage, i.e. the average voltage (DC) and effective voltage (rms) theoretically based on the voltage source parameters and based on the simulation result parameters. The parameters used are peak voltage (maximum and minimum).
4. Comparing the results of theoretical calculations and calculations using simulation parameters as a performance study of the matlab-simulink program for analysing single-phase half-wave diode rectifiers.

DISCUSSION

Simulation of Rectifier with Load R

Simulation of Rectifier with load R in simulink-matlab programme is shown in Figure 10.

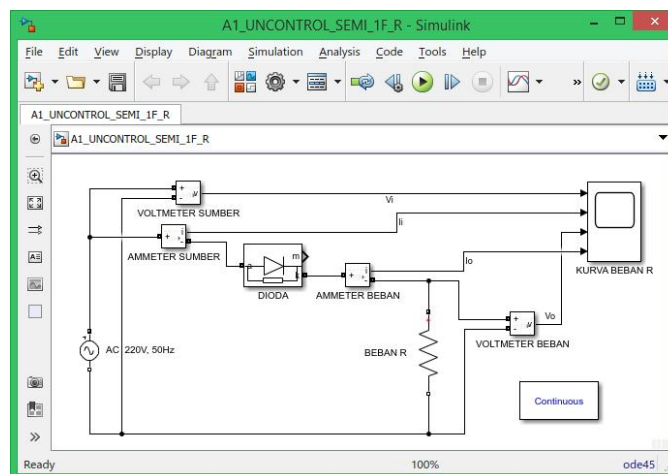


Figure 1-phase uncontrolled half-wave rectifier with load R

The simulation circuit is made as Figure 10, by setting each block component as follows [4]:

a. AC source 220V, 50Hz,

Peak amplitude (V): $[2^{.5} \cdot 220]$

Phase (deg): [0]

Frequency (Hz): [50]

Sample time: [0]

b. Load R,

Branch type: [R]

Resistance (Ohms): [100]

c. VOLTMETER AND AMMETER: [Complex]

d. DIODA, (follow the default), can be set according to the specifications of the diode used/applied,

Resistance R_{on} (Ohm): [0.001]

Forward voltage V_f (V): [0.8]

Snubber resistance R_s (Ohm): [500]

Snubber capacitance C_s (F): $250e-9$

After setting all the block parameters, run the simulation until it is complete, then double-click the 'LOAD KURVA R' block on the rectifier circuit in the simulink working window, to see the input and output waveforms of this rectifier as shown in Figure 11 [4]

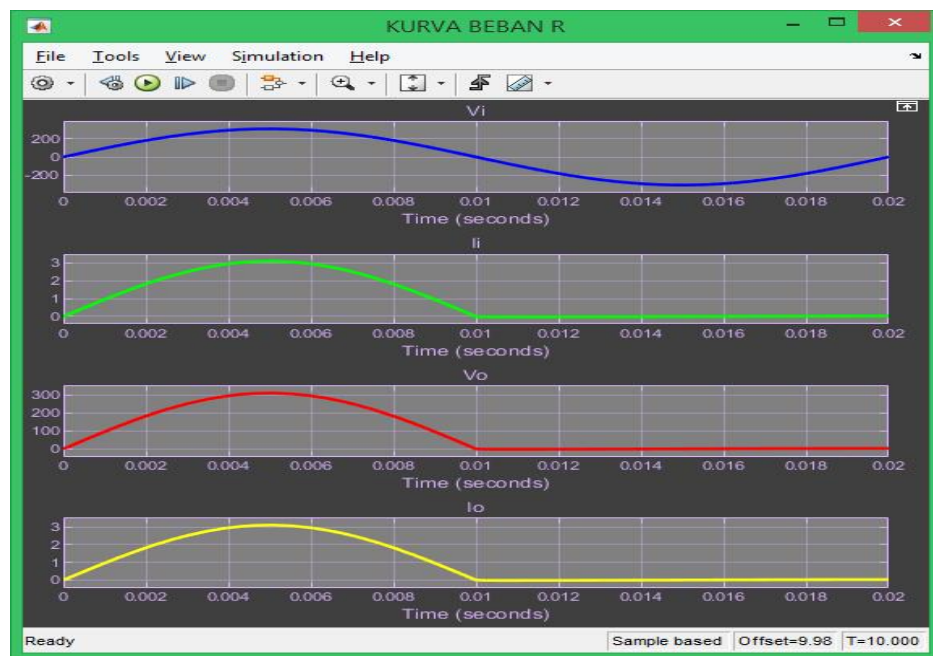


Figure R load rectifier input/output curve

The 'Scope' block named 'LOAD KURVA R' block in Figure 11 shows the rectifier input waveforms i.e. The input voltage and input current, as well as the rectifier output waveforms are the load voltage and load current. Rectifier voltage and current waveforms are displayed for one period of rectifier source voltage () of . Simulation results using the simulink-matlab programme can show the characteristics of the rectifier output, namely the output voltage and current only

exist in the positive half-period/cycle of the source voltage and in the negative half-cycle the voltage and current are held by diodes so that they do not flow to the load R. It can also be seen that for load R the output current is in phase with the rectifier output voltage (and) becomes zero when . By clicking the 'CRUSOR MEASUREMENT' icon and selecting the 'SIGNAL STATISTICS' icon on the tool bar of the 'R LOAD COURSE' window, a window like Figure 12 will appear [4].

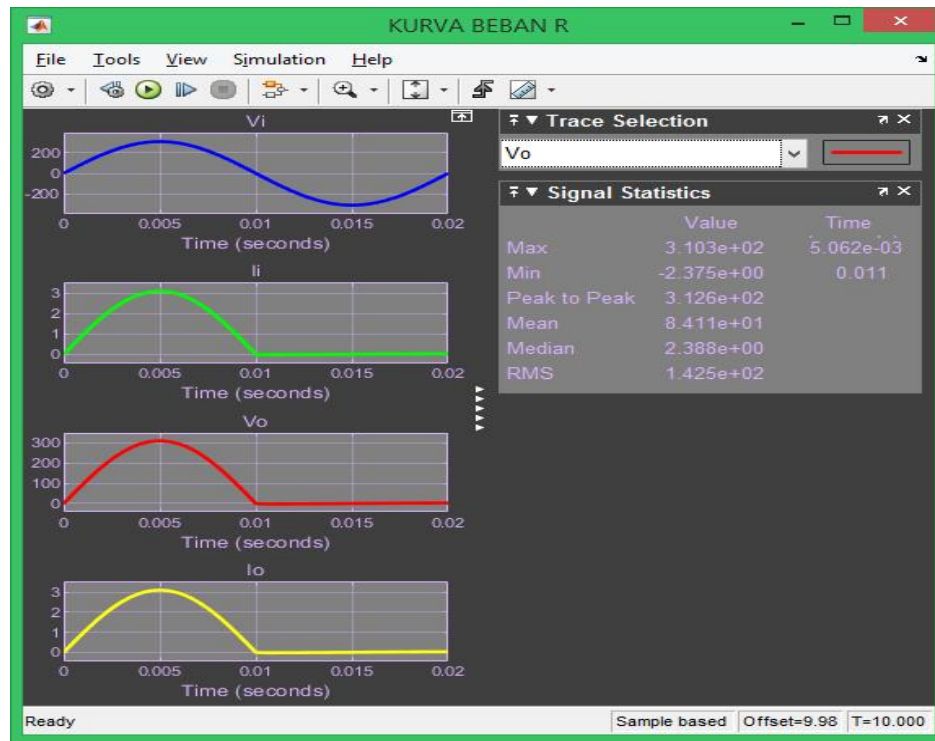


Figure Display window of input and output curve parameter values of rectifier load R

In Figure above the rectifier output voltage waveform parameters (V_o) can be seen as shown in Table 1.

Table 1 Parameter Output voltage (V_o) simulation results

PARAMETER	VALUES
Maximum Voltage	$3.103e + 02 = 3,103 \cdot 10^2 = 310,3 \text{ V}$
Minimum Voltage	$-2.375e + 00 = -2,375 \cdot 10^0 = -2,375 \text{ V}$
Peak to peak Volatage	$3.126e + 02 = 3,126 \cdot 10^2 = 312,6 \text{ V}$
Average Voltage (DC)	$8.411e + 01 = 8,411 \cdot 10^1 = 84,11 \text{ V}$
Effective Voltage (rms)	$1.425e + 02 = 1,425 \cdot 10^2 = 142,5 \text{ V}$

The maximum voltage of the rectifier output which is sought from the rms value of the rectifier input can be sought theoretically by equation (1), i.e., The voltage value is close to the simulated value in simulink 310.3 V. Likewise, the DC average voltage and effective voltage (rms) are calculated using equations (2) and (3) with theoretical peak voltage values (311,127 v) are: 99,034 V and 155,15 V.

For simulated conditions, the average voltage (DC) and effective voltage (rms) can be found with the output wave parameters of the simulation results, namely for the positive half-period peak value (310,3 V) and the value of the theoretical peak voltage ($-2,375$ V). Using equation (2) the average voltage (DC) is 98,02 V and for the effective voltage (rms) using equation (3) is obtained 155.1545 V. The differences between calculations using theoretical values and calculations using simulated values for DC voltage and rms voltage are shown in Table below :

Table Differences in calculations using theoretical peak values and simulated load R

PARAMETER	TEORY	SIMULATION	DEFERENT
Average voltage (DC)	99,034 V	98,02 V	1,02 V
Effektive voltage (rms)	155,15 V	155,1545 V	0,0045 V

Simulation of Rectifier with RL load

Next, the single-phase uncontrolled half-wave rectifier is given a resistive and inductive load (RL) connected in series. The simulation circuit in simulink-matlab is shown as Figure [4].

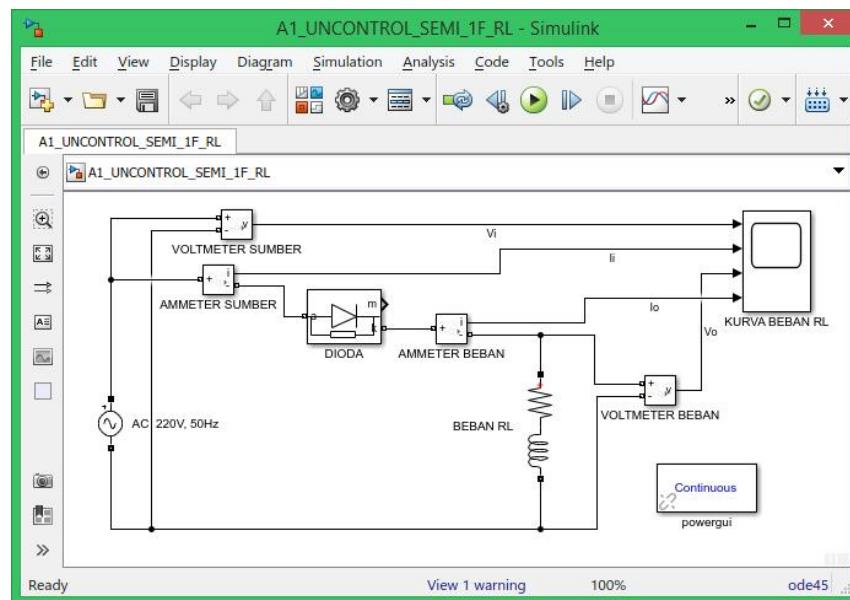


Figure Single-phase uncontrolled half-wave rectifier RL load

After running the circuit of Figure above, the simulation results of the rectifier output shown in Figure 14 [4] are obtained.



Figure Input/output curves of the load rectifier and the load rectifier.

In Figure above it can be seen that the output voltage and output current still flow when the input voltage value is smaller than zero (negative). This is due to the energy stored in coil L, the length of the output voltage and current depends on the composition of the value of R and L as a rectifier load. The parameters of this RL-loaded rectifier simulation are defined by Figure above [4].

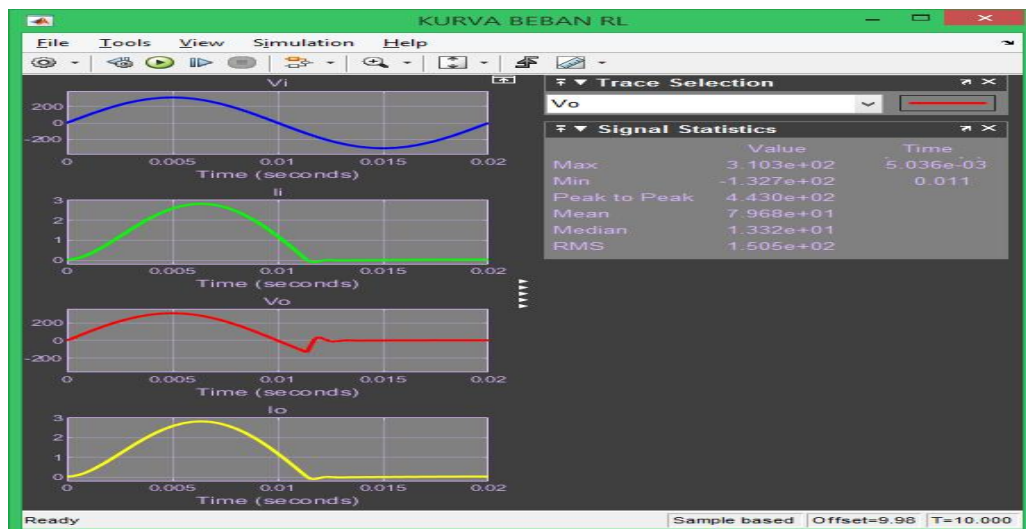


Figure Display window of input and output curve parameter values of RL load rectifier

The calculation result of impedance Z for RL load is obtained: $= 25,23^\circ$, So the load angle ϕ_L is $25,23^\circ$ so that the voltage reaches zero price at the time 3,582 rad. Looking at the maximum and minimum values of the rectifier output voltage V_0 in Figure the average voltage (DC) and effective voltage (rms) can be calculated as follows, The average voltage (DC) is: 96,74 V,

If calculated theoretically using equation (4), it is obtained 94,31 V Likewise, the voltage for effective (rms) is calculated with the maximum and minimum voltage values of the simulation results, obtained: = 155,35 V. If this effective voltage is solved by equation (5), it is obtained, = 156,91 V.

The results of the discussion of this rectifier loaded with a resistive-inductive load and simulated using simulink-matlab show that the calculation of the rectifier output voltage using the simulated parameters, namely the maximum and minimum values of the rectifier voltage output waveform, produces almost the same value as the results of theoretical calculations. Both values and their differences are shown in Table below

Table Differences in calculations using theoretical peak values and simulated RL loads

PARAMETER	TEORITY	SIMULATION	DIFFERENT
Average Voltage (DC)	94,31 V	96,74 V	2,45 V
Effective Voltage (rms)	156,91 V	155,35 V	1,57 V

Thus for a single-phase unrestrained half-wave rectifier or a single-phase half-wave diode rectifier, the maximum and minimum peak values of its output wave obtained from the simulation results of Figure above can be used to find the average voltage (DC) and effective voltage (rms) values of the rectifier output.

Simulation of Rectifier with RL load using freewheeling diode

To analyse this rectifier when connected to a freewheeling diode the simulation circuit is shown in Figure 18 [4].

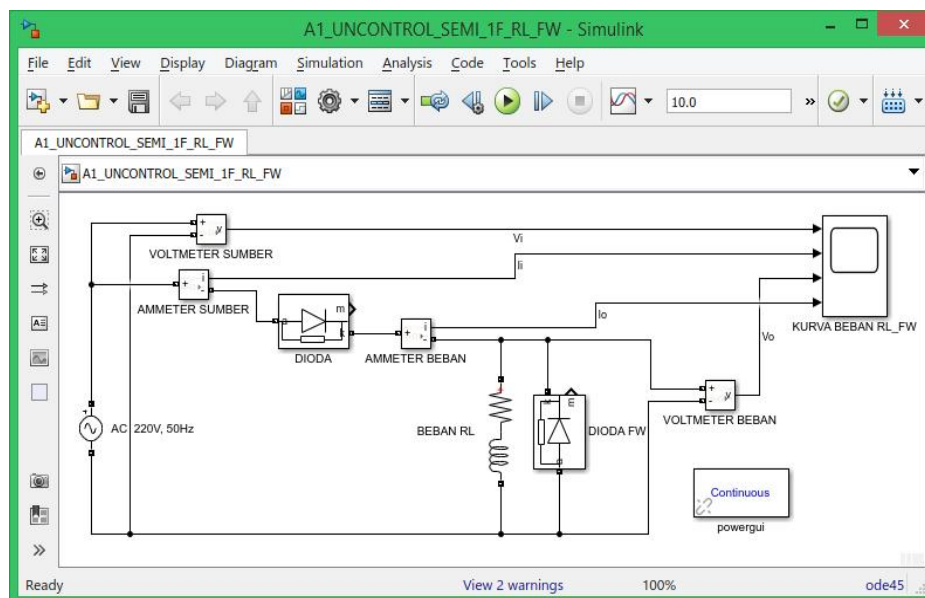


Figure RL-loaded rectifier with freewheeling diode

The simulation results are shown in Figure below [4].

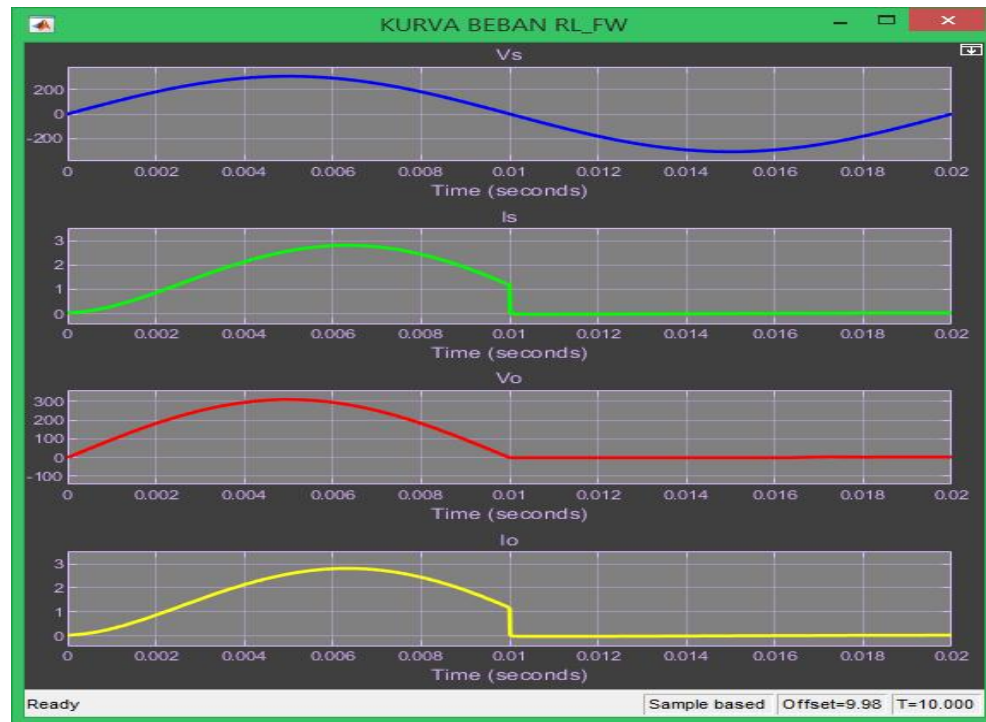


Figure Simulation results of RL-loaded rectifier with FW diode

The calculation results for resistive or mixed (resistive-inductive) load diode rectifiers theoretically and simulation show that there are differences in the values of both DC and effective (rms) voltages. This difference occurs because the matlab-simulink programme can take into account the parameters (characteristics) of the diode that affect the rectifier output wave. Theoretically (ideal conditions) the forward bias resistance of the diode is negligible (zero) and the reverse bias resistance is infinite (∞), so that the peak-maximum voltage at the interval is equal between the source voltage and the load, as well as for the peak-minimum voltage of the load at the interval is equal to zero, so that no source voltage is applied to the load.

Simulation with the matlab-simulink programme produces a peak-maximum voltage when forward biased, the value of which is affected by the diode resistance, because there is a voltage drop on the diode, so that the maximum peak voltage value is smaller than ideal conditions. Similarly, for reverse biased diode conditions, there is a leakage current so that there is a peak-minimum voltage given to the load. This condition causes the results of theoretical calculations and simulations for DC voltage and different. Thus simulations using the simulink-matlab program can show the behaviour of the rectifier output voltage to the load which is influenced by the material characteristics of the diode. With the existing feature facilities in the simulink-matlab programme, the values of the diode parameters can be adjusted according to the technical specifications of the diodes used.

In the figure above, it can be seen that the rectifier output voltage wave curve is the same as Figure 12, namely the rectifier output wave curve loaded with a resistive load R, the voltage is zero

at the time $t \geq 0,01$ s or half-period T , as well as the rectifier output current is zero at the time of the half-period. This simulation can display the output waveform of the rectifier installed with freewheeling diodes, namely the voltage and current waveforms, which eliminate the negative voltage output of the source to the load.

CONCLUSION

The simulation results using the matlab programme with the simulink facility of the single-phase uncontrolled half-wave rectifier are as follows:

- a. The simulation can display the output waveform of the rectifier, namely the output voltage V_o and I_o output current. Likewise, the rectifier input voltage and current (V_i and I_i).
- b. Simulink simulation results can display the output wave parameters of the rectifier, namely the maximum and minimum peak values which are influenced by the characteristics of the diode.
- c. The maximum and minimum peak values affect the calculation results of the average voltage (DC) and effective voltage (rms) values.
- d. Simulation using matlab program can display the output current characteristic curve of rectifier with freewheeling diode.
- e. By using matlab-simulink feature facilities can be set diode characteristics in accordance with its specifications.

REFERENCES

- [1] Skvarenina L. timothy, 2002, The Power Electronics Handbook (Industrial Electronics Series), CRC Press, N. W. Corporate Blvd. Florida USA
- [2] Rashid M. H., 2007, Power Electronics Handbook (Devices, Circuits and Applications), Academic Press an imprint of Elsevier, Burlington USA
- [3] Hass J., Weur M.D. dan Thomas G.B. Jr, 2009, University Calculus (Early Transcendentals), Second Edition, Pearson Education Inc.
- [4] _____ <https://www.mathworks.com/help/simulink/gs/create-a-simple-model.html>, diunduh 25-03-2022